COALBED METHANE (CBM) IN MONTANA: PROBLEMS AND SOLUTIONS

A WHITE PAPER

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INTRODUCTION

Herein CBM refers to the extraction and commercial distribution of methane from subsurface coal deposits. CBM is occurring or possible over large landscapes in New Mexico, Colorado, Wyoming and Montana where multiple coal seams are distributed between other bedrock formations like a layer cake usually at depths less than 1,000 feet.

When ground water contained in the coal is pumped out via drilled wells, the pressure is changed within the deposit, freeing the methane gas. Usual CBM development involves 1–3 wells and associated roads and pipelines per each 80 acres of surface area above the coal layers. Electric water pumping stations, water disposal systems (storage ponds or water pipes to the rivers) and large gas-powered compressors are dispersed among the 80 acre parcels.

CBM is controversial because:

- CBM is a nonrenewable natural resource that is in private and public (mostly Bureau of Land Management) or Tribal (Northern Cheyenne, Crow) ownership in Montana.
- Ownership of CBM and other minerals often is legally severed from surface (land) ownership, creating conflict over land use change.
- CBM extraction entails significant surface modification (land use change) for roads, pipelines, wells and gas concentration facilities, which has secondary effects such as substantially increased noise, dust and access in addition to effects on local social structures associated with incursion of a new or different workforce.
- CBM extraction requires removal (pumping and disposal) of huge quantities of water, often containing very high ion (especially sodium) concentrations, from the coal seams in order to collect the gas.
- CBM reserves in Montana are small compared to very deep reservoirs of gas in Alberta and elsewhere. Montana CBM reserves will be depleted within a decade or so of full development. Nonetheless, CBM represents significant potential income for Montana and owners of the minerals and land.

CBM commercial value in relation to cost of production, especially as influenced by environmental mitigation required by government or the courts will ultimately determine when and to what extent CBM development occurs in Montana. To clarify costs and benefits and bolster pros and cons of CBM development, including short and long-term environmental impacts and potential mitigation procedures, lengthy studies and environmental impact studies have been done (see Box A). As is all too common with complex environmental issues, a tangle of facts, statutes and sentiments constrain CBM problem identification and resolution.

We were asked by Montana legislators to examine the issues and available data in an ecological context and provide a white paper to the State Legislature during the 2003 session. We visited the CBM areas in Montana and Wyoming, discussed issues and data with staff, scientists and consultants from the CBM industry, various universities, Tribes, State and Federal agencies and several nongovernment organizations (NGOs). We obtained and read as many germane documents as we could find.

In this white paper, we focus on the land use change and water quality issues associated with CBM because our professional expertise is in ecology and limnology. We did not consider social or direct economic impacts, nor did we conclude whether full, partial or no CBM development is in the best interest of Montana. Our goal with this white paper is to frame the ecological issues related to development of CBM in Montana, especially the relative risk of water pollution in relation to discharge and treatment technologies. We conclude with an ecosystem-based decision process that can be used by government to untangle CBM in Montana.

Box A. The information base.

A large number of agency, tribal and industry reports contain data and interpretations about Coalbed Methane (CBM) in the Powder and Tongue River Basins of Montana and Wyoming. Few of these reports are peer-reviewed scientific papers.

- Locations and geology of coal deposits and associated groundwater conditions have been especially well documented by the Montana Bureau of Mines and Geology of Montana Tech of The University of Montana.
- Surfacewater discharge and chemistry has been documented at various sites along the Tongue and Powder Rivers by the US Geological Survey.
- The CBM industry has funded a number of studies concerning ways to condition local soils to allow use of high sodium water from the gas production process to irrigate crops. A very few and mostly nonquantitative analyses of potential impacts on current condition of terrestrial and riverine biota are available.
- The US Bureau of Land Management has conducted a Federal environmental impact study (EIS) as part of its responsibility for management of public lands.
- The Section 300 series of the Federal Clean Water Act applies to potential water pollution associated with CBM, along with Montana statutes pertaining to nondegradation and constitutional right of a "clean and healthful environment."
- The Montana Department of Environmental Quality (MDEQ) has regulatory responsibility for the State; whereas the Environmental Protection Agency wields Federal authority. Both agencies have conducted analyse of CBM impacts and the MDEQ has proposed regulatory standards based on analysis of impacts of CBM water on agricultural soils.
- The US Fish and Wildlife Service may become involved if CBM is shown to impact organisms listed under the Federal Endangered Species Act, and apparently, a few candidate species may exist in the Montana CBM area.

THE MONTANA CBM AREA

The Powder and Tongue River Basins contain the most accessible CBM deposits in Montana. The area is a large geosyncline with coal deposits dipped toward the center, most at depths less than 1,000 feet sandwiched between shales and sandstones. These are traditional farming and ranching lands with considerable wildlife value. CBM development in Montana currently is limited to a small area near the Tongue River close to Decker, Montana. However, the headwaters of the Tongue and Powder rivers are in Wyoming where CBM extraction is more advanced.

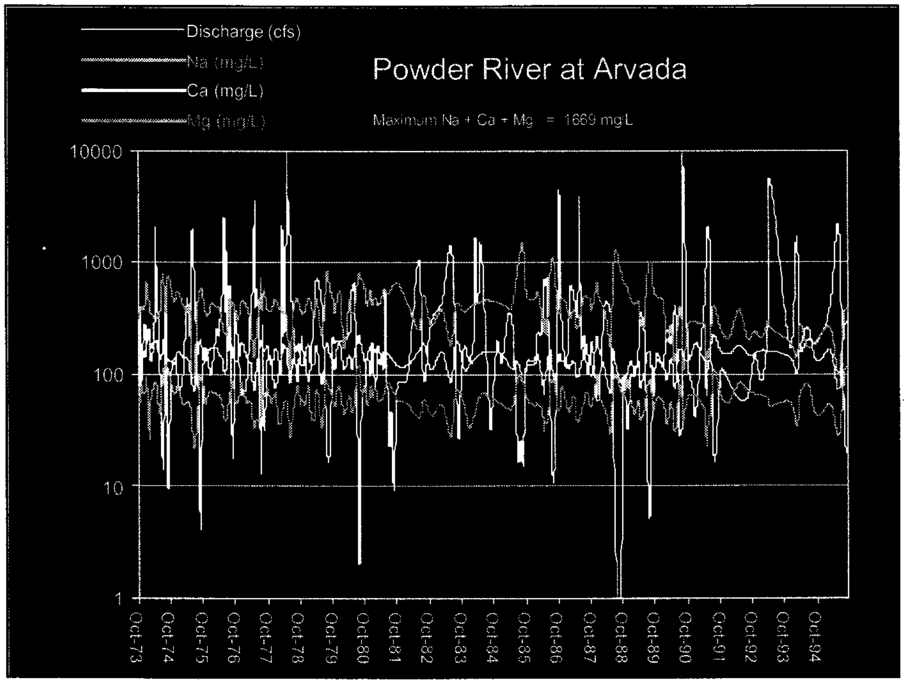
Ecologically the area is dry short grass prairie and ponderosa pine steppe. The few streams and rivers are warm in summer and are much more turbid and salty compared to mountain rivers of western Montana. They contain the biota of the Missouri River system, including many nonnative species such as carp. Some fishes and invertebrates are potential endangered species candidates. Wildlife is abundant and adapted to open range and some species, such as sage grouse, are becoming relatively rare owing to loss of habitat. Because most of the CBM area remains open range, it functions as a reserve for short grass prairie wildlife and plants. Scarcity of surface waters is an important natural feature of this landscape. Springs from perched aquifers are rare and many tributary streams are ephemeral, flowing only during wet periods. Water for livestock is often limited and for many years people have tapped ground water in the coal beds with wells for livestock and domestic use. Irrigation water from the main stem Tongue and Powder Rivers sustains much of the farming. Water diversion from the rivers is substantial and base flows on dry years are little more than a trickle.

The Powder River is inclusively a prairie river with lowland headwaters in salty shale formations; whereas the Tongue is a mountain river with headwaters in the hard rocks (granitic) of the Big Horn Mountains. Hence, the two rivers differ by an order of magnitude in salt content (compare illustrations in Figure 1), which is key to CBM development. The Tongue is more dilute and therefore, more easily degraded by inflow of high sodium CBM water. However, in the Powder, inflows of additional salts from CBM exacerbate the naturally high salt load. Indeed, Montana water quality regulators have been concerned about salt pollution from Wyoming CBM activities degrading water in the Montana portions of the rivers. Threshold or exceedance (numeric) criteria have been established through negotiation between Montana and Wyoming regulators. But, such criteria are difficult to enforce because the stochiometry of the salt ions is not completely coherent with discharge. That is, the relative contribution of ions such as calcium, sodium, magnesium, sulfate and chloride, which make up most of the dissolved solids loads, do not change proportionally as flow in the river varies (i.e., note the extreme variance in salt content with discharge in Figure 1). Thus a numeric standard for sodium may not ensure protection of water quality. How to regulate discharge of CBM waters into these rivers remains largely unresolved in Montana except in the context of the demonstration sites.

LAND USE CHANGE ASSOCIATED WITH CBM DEVELOPMENT

According to the draft Environmental Impact Statement (EIS) for CBM in Montana, as many as 20,000 wells may be operational in Montana to bring the accessible coal seams to full development. This translates to local densities of one or more wells per 40 acres, with associated roads, well pads, pipelines, generating and gas concentration stations and disposal ponds, if the practices we observed in Wyoming and Colorado and at the Montana demonstration sites are followed.

Therefore, considerable landscape modification clearly will occur (e.g., see Figure 2). It would be possible to actually quantify the total disturbed areas in recently developed CBM fields using spatially explicit analysis of contrasts in before and after photos as in Figure 2. However, substantial land use change is obvious. Of course, disturbance can be minimized with careful advance planning and reseeding of pipeline routes and many of the access roads. Reseeding with native grasses is an aggressive practice by industry to reduce erosion and invasion by weeds, but effectiveness is not routinely measured as far as we could determine. Nonetheless, we observed weed free reseeded native grasses actively growing on pipeline routes and road berms in the Montana demonstration sites.



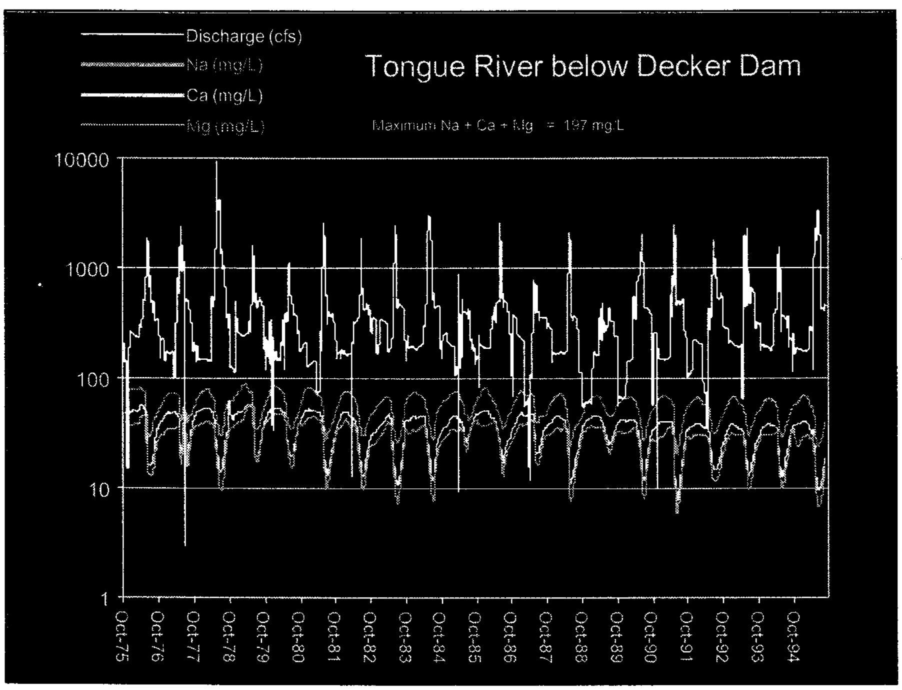
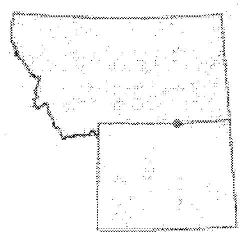


Figure 1. Discharge (cubic feet per second) and Sodium (Na), Calcium (Ca) and Magnesium (Mg) concentrations (mg/liter) in the Powder River at Arvada, Wyoming and in the Tongue River below Decker Dam near Decker, Montana, during the two decades preceding coalbed methane development in either Wyoming or Montana.



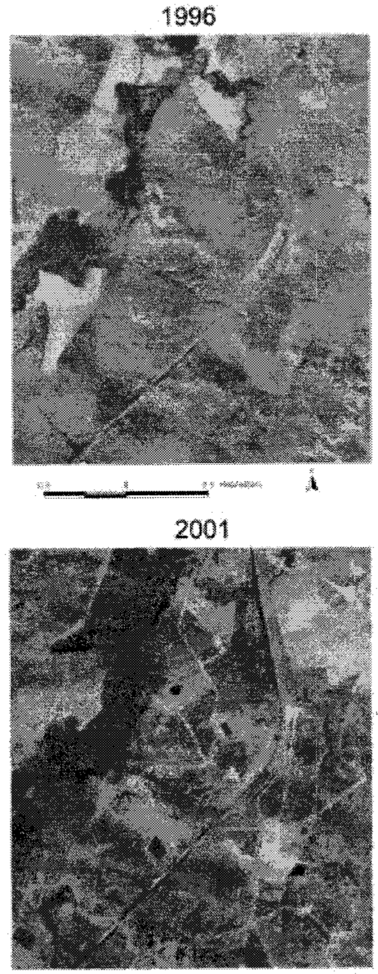


Figure 2. Photos of CBM gas field before (1996) and after (2001) CBM development. This site is located on the Wyoming side of the Tongue River and illustrates the change in land cover and use as CBM wells, compressors, pipelines, access roads and storage ponds are constructed.

Documented effects of CBM development on wildlife are sparse and certainly not specific to Montana. But there is a large body of scientific literature showing mostly negative trends for native biota directly associated with increased access, noise and human contact in previously unroaded or minimally roaded areas. This underscores the likely negative influence this development will have in the context of this region as a fairly intact and very large grassland steppe ecosystem. However, we emphasize that significant moderation may occur in the long term, if animals are not harassed. Simply, most wild animals get used to human incursions as long as the habitat is in good shape and harassment is prevented. Moreover, there have never been any restrictions on access other than in the context of private property in this area of Montana and wildlife populations for the most part seem robust.

Nonetheless, land use change should be predicted using remote sensing tools discussed below and actual changes carefully documented. As well, better studies of wildlife dynamics should be designed and undertaken prior to development to better understand how to make CBM and wildlife get along if development does proceed.

Influences on livestock probably are less problematic, except as relates to change in forage availability. In general, forage is not likely to be greater after development, at least in the short term and synergistic effects linked to extreme precipitation variation observed in the last decade may occur. Again, this should be much more clearly considered and documented.

THE CBM WATER PROBLEM: A LOT OF WATER WITH HIGH DISSOLVED SOLIDS CONTENT, ESPECIALLY SODIUM

The quality of ground water that will be pumped to the surface by CBM varies across the landscape. As noted above, CBM water has been used for years in households and livestock tanks after degassing the methane. This water does not contain toxic compounds. Indeed, a recent court decision stated that unaltered CBM ground water is not a pollutant in the context of the Clean Water Act and does not require a discharge permit. This decision currently is in appeal. Regardless, CBM water has very high sodium content. Sodium reacts with natural clays to produce greasy soil when wet and a hard pan when dry, which impairs or prevents plant growth. We observed areas with little or no plant growth where CBM water has been spread, although there apparently are not a lot of these places. The petroleum industry has a long history of dealing with salty water, mainly by reinjection deep into the ground or by containing the water carefully in sealed ponds.

The quantity of this high sodium ground water to be dealt with is huge. Each CBM well will produce 2.5–10 gallons of water per minute, according to the EIS and based on the Montana demonstration sites. Simple extrapolation to 20,000 wells producing water and gas at full field development means that 110–450 cubic feet per second of CBM water has to go somewhere. To be fair, not all wells will operate at the same time and effluent will be generated over a large area. Nonetheless, the estimated potential volume of CBM water flow from the gas fields exceeds the base flow of both the Tongue and Powder Rivers (see Figure 1). To put this in another context, consider that a range cow consumes about 16 gallons of water per day and requires 20–50 acres of range land for grazing per year in this dry area of Montana.

Ground water in the coal seams has dissolved solids concentrations that vastly exceed values of natural surface runoff shown in Figure 1. Translated to values of electrical conductivity (EC) and sodium adsorption ratios (SAR), the EIS predicts that water produced during CBM development has an EC value of 2,200 ΓS/cm and a SAR value of 40. These values, especially the SAR values, are well above almost all of the existing instream values ever recorded. Such water cannot be used to irrigate crops unless desalinized or substantially diluted or unless the soils are treated with a combination of gypsum and/or acid to counteract the clay-sodium interaction that causes the soil particles to disassociate and thereby changing soil structure adversely for plant growth. The conclusion is that direct discharge to the rivers of that much CBM water will change the chemistry of the rivers to the extent that use by native biota and by farms could be impaired.

What can be done about the CBM water, then? Industry currently is trying to contain CBM water in ponds (Figure 2) and limit direct discharges into the rivers. Ponds are expensive to build and cover a lot of space that ultimately will be useless salt pans when methane extraction is exhausted and the ponds evaporated. The pond beds will be high salt sources for decades if allowed to contact surface runoff. Dams may fail or leak. CBM water in some of the ponds (referred to as percolation ponds) is intentionally allowed to percolate downward into subsurface formations as a disposal process. But the ultimate flow pathways for this water is not necessarily back into the coal seams, especially if the water encounters shallow impervious formations. Uncertainty is high as to where this water will go. Industry also is conducting experiments to dilute or treat soils to allow irrigation with CBM water, but results so far are not promising in a commercial farming context.

Why not reinject the water into depleted coal seams or other subsurface formations as is usually done? Clearly this would solve one of the biggest problems with CBM. The answer we got consistently is that it is cheaper to build ponds or discharge the water directly into the streams and rivers. Moreover, most of the subsurface strata are impervious shales that are not amenable to reinjection. Ideally, one would start at the highest elevation coal seam, dewater it and then sequentially develop lower elevation sites, backfilling the water to the degassed deposit.

Reverse osmosis treatment (desalinization) could be applied to strip the salts thereby producing water suitable for all uses, but this also is expensive and the striped and greatly concentrated salts have to be dealt with.

Industry of course is interested in direct discharge to the streams owing to expedience and least cost. However, the volumes of water and concentrations of sodium and other ions described above would very likely be harmful to river biota and ecological processes as well as harm irrigated agricultural lands. The salient issue is whether there are reasonable limits that can be applied to control or regulate such discharges. The Montana Department of Environmental Quality has proposed numerical criteria or standard thresholds (Table 1), based primarily on use of the water for irrigation as opposed to standards for both river biota and irrigation. The process of deriving these standards included consideration of soil types and ability of soils to withstand additional salinity, particularly as measured by EC and SAR. It also included compromise between CBM industry's desire to minimize disposal costs and concerns on the part of irrigators that river water be consistently suitable for irrigation. The standards (Table 1) would allow both Tongue and Powder rivers and Rosebud Creek to be loaded with salts to the point that the high end of the current variability (see Figure 1) could be maintained by CBM discharges. In other words, these standards allow significant salt loading over existing conditions.

The main take home point from all of this is that based on the current science, predicting the short- or long-term consequences, if any, on irrigation supplies or riverine ecosystem functions and biota is decidedly uncertain. Moreover, as noted above, current water quality statutes may not specify that discharge permits are required at all. In short, dealing with CBM water in a documented, sound fashion, short of reinjection, is fraught with scientific uncertainty. Erring on the side of expedience could produce impacts that could last for decades, if not permanently change the existing environmental condition.

Table 1. Numeric standards for discharge of CBM water into various water bodies of the CBM area in Montana proposed by the Montana Department of Environmental Quality (EC = electrical conductivity- as μS/cm, SAR = sodium absorption ratio, all values are monthly means)

Location, parameter*	Proposed Standard
Tongue River main stem:	
EC irrigation season	1,000
SAR irrigation season	3.5
EC nonirrigation season	2,000
SAR nonirrigation season	5.0
Powder and Little Powder River main stems:	
EC irrigation season	2,000
SAR irrigation season	5.0
EC nonirrigation season	2,500
SAR nonirrigation season	7.5
Rosebud Creek main stem:	
EC irrigation season	1,000
SAR irrigation season	3.5
EC nonirrigation season	2,000
SAR nonirrigation season	5.0
Tributaries & other surface waters in above basins:	
EC irrigation season	500
SAR irrigation season	5.0
EC nonirrigation season	500
SAR nonirrigation season	5.0

* In all rule proposals irrigation season is from March 2-Oct 31, nonirrigation from Nov 1 to March 1.

AN ADAPTIVE MANAGEMENT – ECOSYSTEM APPROACH TO THE CBM WATER ISSUE

Many people would like to have CBM development in Montana as long as there are no costly and lasting environmental problems. The path to such a goal clearly is a tangled one. An iterative process integrating stakeholder concerns with the best available science, composed of focused research, monitoring and evaluation of effects, is required to resolve uncertainties if CBM moves ahead in Montana. In Figure 3, we offer an adaptive, ecosystem framework for accomplishing the goal. Note this process allows for the goal to be changed if it becomes too costly in either economic or environmental terms. Our focus herein is on the CBM water issue. But, this framework can be used to resolve any issue.

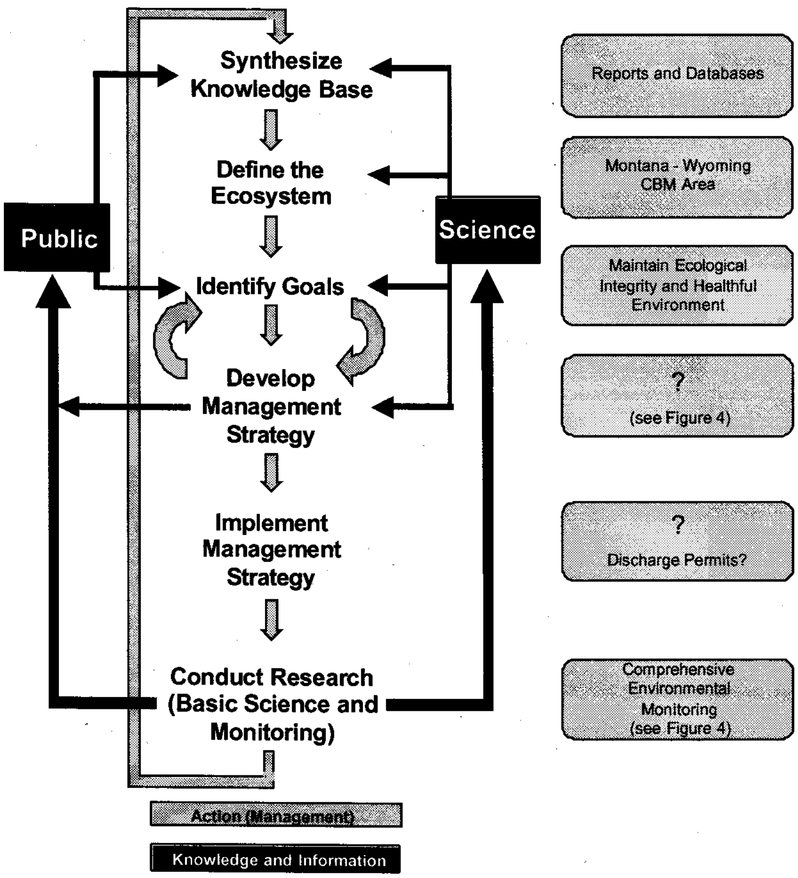


Figure 3. General protocol for ecosystem management (flow diagram at left) as applied to Montana CBM (blue boxes on right). This is not an EIS process. It is an adaptive process that must continue for the life of the project because new information may change outcomes at any level. Complete rationale for this approach is given in the 1996 issue of the journal Ecological Applications 6(3): 741-744.

With respect to the water issue, the process currently is stuck at the Management Implementation step in Figure 3. Here is how to get beyond the mud hole.

We summarized above the array of mechanisms the CBM industry is using to dispose of the ground water brought to the surface for the extraction of methane gas from the coalbed seams. In Figure 4, we have ordered the uncertainties and environmental risk associated with these mechanisms from the least risk (top) to the highest risk (bottom) with respect to potential degradation to the surface freshwater environments in the Montana CBM area. This "Decision Tree" is a hierarchical sequence of linear logic for assessing the various alternatives for dealing with the potentially vast quantity of salty CBM water. In each case, a specific mechanism of disposing of the water must have an approach to achieve nondegradation of the surface freshwater environments. In Figure 4, we provide some suggested approaches to nondegradation for each mechanism.

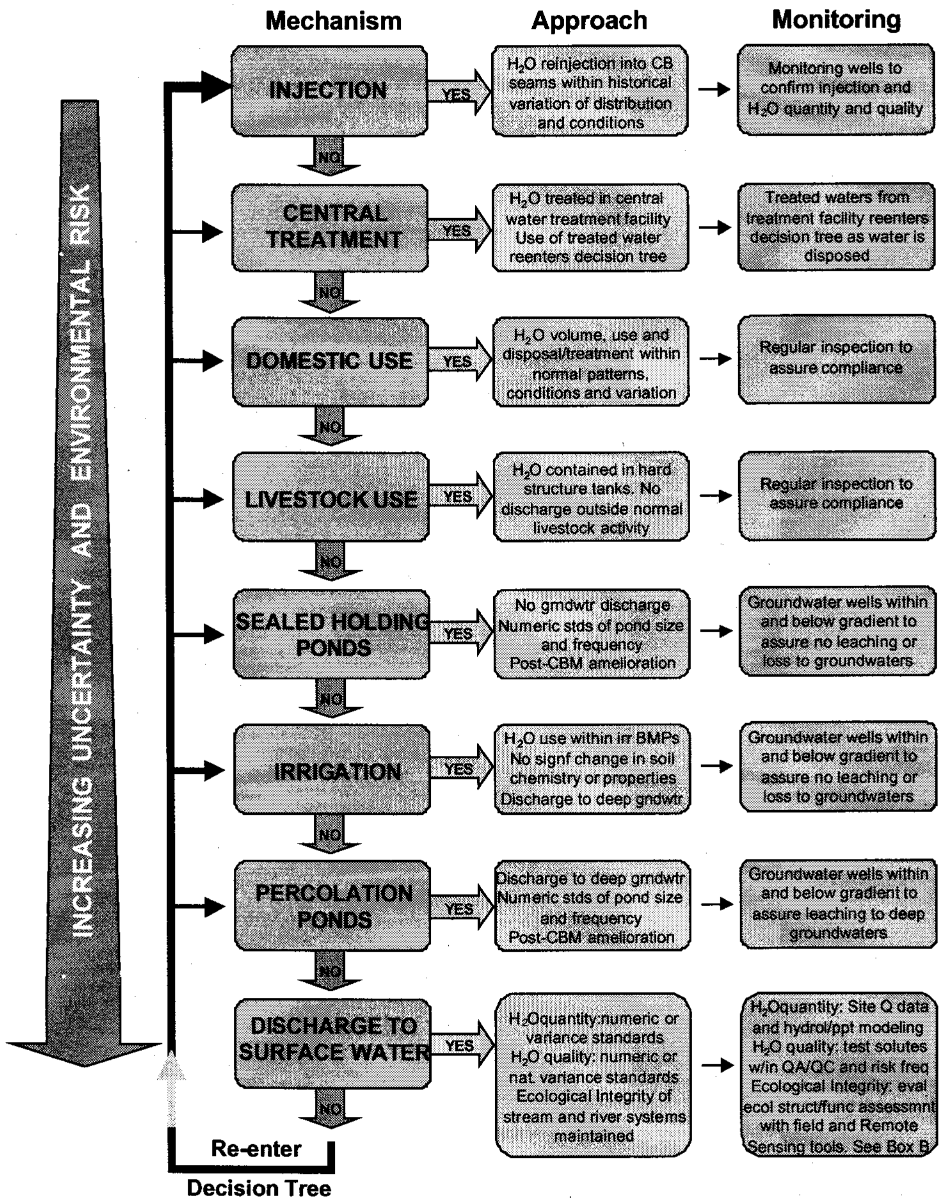


Figure 4. Adaptive management Decision Tree illustrating increasing uncertainty and environmental risk associated with the disposal or treatment of CBM ground water. "Mechanisms" refer to sequential decision boxes associated with the various common methods of CBM water disposal. "Approaches" refers to a possible approach or limitation to risk. "Monitoring" highlights a possible monitoring alternative.

An array of research and monitoring tools exist that could be put to good use to resolve uncertainties for water and other CBM issues (Box B). For example, land use change in many different contexts (wildlife, water quality, soil condition) can be evaluated for the entire CBM area using new remote sensing tools. Models and advanced computing tools are available to assess cumulative effects and may be improved by local determinations of cause and effect (e.g., details of soil responses to various sodium levels). Without a robust research component, the iterative process idealized in Figure 3 will tilt toward litigation and the courts as the problem solver.

Box B. Monitoring and Assessment Tool Box

- Satellite Imagery to assess and model landscape change

  Numerous satellites, such as Land-sat and EOS, produce an array of remotely sensed data that are readily available. Digital imagery permits monitoring and modeling of land use, vegetation cover, landscape change, and other important parameters that will be affected by CBM development. Assessment and modeling of landscape change would permit Montanans to make informed decisions in an adaptive management context.

- Monitor and model precipitation and hydrologic discharge of entire basins

  There are sophisticated models of regional climate and hydrologic discharge with datasets ready-to-go for Montana. Water quantity and quality are central issues in the CBM development for Montana. Assessment and modeling of water coming into and passing through the CBM basins is critical to understanding and evaluating CBM development effects on Montana's environment

- Nano-sensors for continuous in-stream monitoring of H_2O chemistry

  Recent development of nano-sensors for water chemistry now permit continuous monitoring of the parameters of greatest concern to Montanans in the development of CBM. Scientists are no longer relegated to only spot sampling. Montana's agricultural and ecological interests could be well served by this new technology.

- Ecological assessment of Ecosystem Integrity

  Significant advances in biological and functional assessment permit rapid evaluation of species and processes in the natural environment. Assessment is based on a *Tiered Aquatic Life Use* model developed cooperatively with the US EPA. These evaluation and modeling approaches facilitate direct assessment of aquatic populations and communities such as fish and food webs.

- Hyperspectral Airborne Remote Sensing and Habitat Analysis

  Recent developments in airborne hyperspectral imagery now permit detailed evaluation of change in aquatic and riparian habitats. Montana now has the capability of assessing river processes and habitats along entire stream and river corridors at resolutions of 1 square meter.

These are examples of environmental monitoring and evaluation tools used routinely by FLBS and other scientists in Montana, in the Pacific NW, and around the globe. For details, contact Flathead Lake Biological Station of The University of Montana.

CONCLUSION

CBM is especially problematic in that gas production will benefit Montana economically, but at the same time considerable uncertainty exists about lasting environmental impacts of full field development, especially with respect to land use change and water quality.

The water problem could most simply be solved by reinjection. If reinjection is not an economical option, the issue of what to do with the water becomes complex. Ponding and direct discharge both have potentially very long lasting ramifications. Using our decision tree (Figure 4) hopefully will help better quantify the various alternatives. In any case, it is critical that a robust monitoring plan be implemented to ensure that the existing water quality is maintained. Loading the rivers with CBM salt water to the current limit of maximum variation will not sustain water quality, biota or agricultural use.

Land use change must occur in order to extract the gas. Minimizing impacts on wildlife and other attributes of the current natural character of the area will require implementation of best management practices (BMPs) for installation and operation of the gas fields. No uniformly accepted BMPs exist for CBM activities as far as we know. A decision tree for field development (e.g., road and pipeline restoration, access, noise), similar to what we have derived for water disposal could lead to a robust set of BMPs.

Finally, more insightful and independent research to determine environmental problems and solutions must be conducted to reduce uncertainties. Key questions such as access and noise effects on wildlife, effectiveness of native vegetation restoration in disturbed areas and influences of CBM water on river biota and farm soils requires robust experimental designs. This work should be peer reviewed and published in the scientific literature as a credibility check.

Who will pay for these activities? Certainly State, Federal and Tribal governments must be involved in monitoring and evaluation. But, ultimately it seems the producers of the gas should pay for environmental safe guards and clean up that may eventuate over the life of the project. A permitting and bonding system that is robust and fair could accomplish this, if it is implemented in an adaptive ecosystem management framework (Figure 3).